BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Additional Opportunities for Data from the 1969 Mariner Television Experiment - Case 710

DATE: May 27, 1968

FROM: G. A. Briggs
P. L. Chandeysson
W. B. Thompson

ABSTRACT

Two possible amendments to the 1969 Mariner Mars flyby television experiment mission plan are suggested. The first involves orientation of the rectangular field of view of the high resolution vidicon tube to optimize chances of including the moons of Mars in the planned sequence of far-encounter photos of the full Mars disk. The second suggestion is to provide multispectral full planet imagery of Mars rather than the planned black and white sequence. This would involve either adding color filters to the B camera for its planned far-encounter sequence, or use of the A camera, which has two filters but is currently reserved for the near-encounter sequence. As operational constraints may preclude any full planet photography from follow-on Mars orbiters, the far-encounter phase of the '69 mission may be the last opportunity for full planet multispectral imagery from Mars spacecraft for many years.

(NASA-CR-95474) ADDITIONAL OPPORTUNITIES FOR DATA FROM THE 1969 MARINER TELEVISION EXPERIMENT (Bellcomm, Inc.) 12 p

N79-72636

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No. 602
CR-95474
(NASA CR OR TMX OR AD NUMBER) (CATEGORY)

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MEMORANDUM FOR FILE

I. INTRODUCTION

A. Background

The three scientific objectives for the 1969 Mariner Mars flyby television experiment[1] can be briefly summarized as the acquisition of data bearing on: (a) topography and seasonal variations of the planet surface; (b) the planet origin; and (c) crater morphology (as a clue to planet history). The mission is planned to consist of 2 spacecraft to be launched during the period February - April, 1969.[2] One spacecraft will pass the planet at high southern latitudes to photograph the polar cap region in the spring season. The other spacecraft will pass near the equatorial region. Nominal periapsis altitude is about 3000 km (~10,000 km for Mariner IV).

The television experiment will use two boresighted vidicon cameras. Camera A has a wide field of view (11°x14°) with the camera B field of view (1.1°x 1.4°) located at its center. Both cameras have 704 TV lines/frame digitally encoded to 945 picture elements/line.[3] The wide angle camera is provided with orange and green filters. Presumably these are similar to the Mariner IV color filters. The narrow angle camera takes only black and white imagery.

The photographic mission consists of a far-encounter and near-encounter sequence. The far-encounter sequence is designed to provide full planet black and white pictures of Mars. Approximately eight pictures will be taken at 4 hour intervals with Camera B during the period from 46 to 18 hours before periapsis passage. The near-encounter sequence will consist of two phases lasting a total of 18 minutes as the spacecraft passes the planet. The first consists of a sequence of 17 pictures at a constant phase angle of about 45°, with the second being a sequence of 8 pictures at a phase angle of about 90° (all Mariner IV pictures were at a phase angle of about 60°). The wide angle pictures will be partially overlapping and will alternately use the orange and green filters. The high resolution narrow angle pictures will be nested in the low resolution overlap region.

B. Purpose

The purpose of this paper is to point out two additional possibilities for enhancing the data return from the Mariner '69 television experiment. Both of these opportunities occur during the far-encounter phase of the photographic mission, although there are ramifications which could be pursued during the near-encounter phase. The first possibility discussed considers selecting the orientation of the rectangular field of view of the Camera B vidicon tube to maximize the chances for detecting the natural satellites of Mars at the time when full planet black and white photographs are normally being taken. The second possibility is the acquisition of full planet multispectral photography. This would provide a check on earth-based data which has revealed a planet diameter that appears to vary with color. It should also prove valuable in the interpretation of the near-encounter multispectral photos of the '69 mission.

II. PHOTOGRAPHY OF THE MARTIAN MOONS

At 18 hours before encounter Mars just fills the field of view of the narrow angle high resolution camera. At this time the angular resolution on the surface of Mars is about 10 km per scan line. Since the moons are about one scan line wide (Phobos is estimated at 19 km in diameter and Diemos at 10 km), they should be detected as small points of light if they are within the field of view and against the dark sky background. This assumes that the albedo of the moons is approximately the same as Mars. The moons of Mars do not show up on earth-based photographs of Mars because they are much smaller than the resolution of these pictures. It is necessary to greatly overexpose Mars to detect the moons in earth-based photographs.

The probability of either of the two moons being within the field of view and against the sky background depends on when the picture is taken and the orientation of the rectangular format. The time of the exposures is probably fixed by other considerations such as getting good longitude coverage of the planet, but the format orientation might be selected to favor photography of the moon.*

*The orientation of the rectangular format for the wide angle pictures will probably be selected to achieve maximum overlap. The narrow angle camera, however, should have a less constrained orientation.

The moons rotate about Mars in very nearly the equatorial plane and since the approach trajectory is near the equatorial plane, the moons should appear to be moving in very elongated ellipses around Mars. Orienting the rectangular format so that a diagonal is parallel to this elongated ellipse maximizes the probability of catching the moons in a photograph. Figure 1 shows the probability of photographing the moons in a single random* picture taken when the planet diameter subtends 1.1°, i.e., when the planet fills the field of view. These probabilities were calculated using the simplifying assumption that the approach asymptote is in the orbit plane of the moons. This makes the moons appear to move back and forth in a straight line rather than a narrow elipse. The maximum at 37.6° occurs when this line of motion coincides with a diagonal of the format. The most favorable angle may be somewhat different if the actual approach geometry is used, but clearly the chances of photographing the moons can be improved by orienting the format properly before the mission is flown.

If the '69 Mariner camera uses an electrostatic vidicon tube like the '64 camera, the orientation of the format is determined by the orientation of the tube within the camera. Changing the orientation involves rotating the vidicon tube and its socket. Thus the format orientation might be changed without great difficulty even after the cameras are built.

III. FULL PLANET MULTISPECTRAL IMAGERY OF MARS

A. Scientific Value

Multispectral full planet photographs of Mars at an improved resolution could be used to make advances in a number of important areas, notably in the study of various atmospheric and surface phenomena and in the determination of the radius of the solid planetary body. In addition, by providing information about the color properties of the planet, such photos could be used as references with which to compare and interpret lower resolution earth-based telescopic photographs covering a much more extensive range of conditions at the planet.

Measurements by some authors have indicated that the apparent radius of Mars is greater in yellow and blue light

*Random in the sense that no knowledge of the absolute position of the moons is assumed.

than in red and suggest that, at the former wavelengths, atmospheric layers are being observed at the limb. Measurements of radius are difficult to perform accurately and it is not clear that such an interpretation of the measured values is justified. Multispectral photographs of much higher resolution than is presently available could be used to obtain a more accurate value for the Martian radius and to learn more about the atmosphere above the limb.

Telescopic photographs of Mars taken through appropriate filters reveal a number of atmospheric phenomena including yellow and white clouds and the remarkable "blue haze." As a result of the haze, the surface features (except the polar caps) are almost entirely obscured in blue light, but on occasion, interesting "weather bands" have been observed. High resolution multispectral photographs of the planet as a whole are probably the key to the attainment of a reasonable understanding of the nature of the Martian atmosphere.

Although the coloration of Mars is dominated by the red deserts and the white polar caps, virtually every other color has been reported to have been seen, especially within the mare regions. Mars is subject to seasonal variations of albedo and, apparently, of color leading to speculation about the possible presence of life forms. It should be noted that the surface of Mars can be photographed in blue light only through clearings in the "blue haze" which generally occur locally, and it is likely that the greatest chance of finding such clearings is to be obtained by full planet photography.

B. The '69 Mariner Opportunity

There are at least two techniques for using the '69 Mariner television data to improve on the determination of the diameter of Mars. The one which employs full planet multispectral photos is probably less accurate but does give data over the entire visible disk. This technique would employ photos taken with the wide angle camera (Camera A) using color filters at the time when the planet nearly fills the field of view. This vidicon has a resolution at the planet of about 27 km/line pair (assuming .35 line pairs/scan line). It should be possible to measure the planet diameter to at least the resolution of one line pair.

This quality of information should represent some improvement over the current state of affairs in earth-based attempts to determine the Mars diameter. De Vaucouleurs[4] has recommended provisional acceptance of the following set of values:

Equatorial diameter in red light	∿6750 ± 20 km
Polar diameter in red light	∿6700 ± 20 km

The interpretation is that these values portray the solid surface. Telescopic observations in yellow light reveal an equatorial diameter approximately 100 km larger, with a corresponding increase of about 70 km in the polar diameter. This is assumed to reflect some scattering property of the lower atmosphere which was not apparent in red light.

By contrast the Mariner IV radio occultation experiment yielded a value for the Mars diameter of about 6763* km at mid-latitudes (40-60°). Presumably this value should be intermediate between the polar and equatorial solid planet diameters recommended by de Vaucouleurs, i.e., about 6725 km. Furthermore, it should be pointed out that de Vaucouleurs' survey of experimental results on the determination of the Mars diameter reveals a difference of over 200 km between extreme values, although most have an estimated error of only several tens of kilometers. In view of this degree of uncertainty, it would seem that full planet photos with several different filter settings taken during the far-encounter phase of the '69 Mariner flyby would be more definitive.

A second technique for obtaining the Mars diameter from television experiment results does not require full disk photography and hence can use higher resolution data for a more accurate diameter determination. The technique requires knowledge of the spacecraft position and the direction of the camera axis at the time of near-encounter limb photography. With a nominal periapsis altitude of 3000 km, the limb can be photographed at a range of about 6400 km. Using the wide angle camera the resolution at the limb would be about 5 km/line pair. Assuming a spacecraft location accuracy of a few kilometers (relative to the Mars center of gravity) and a camera pointing accuracy of about 1 milliradian, the radius could be determined with an error of about 10 km. If the spacecraft location accuracy were a kilometer or less and the camera pointing uncertainty were more like 0.1 milliradians, it would be worth using the narrow angle camera (Camera B) which has a factor of 10 better resolution.

*Two values for the radius were actually determined: 3384 ± 4 km on entry and 3379 ± 4 km on exit from occultation.(5)

Uncertainty in the radius determination might approach 1 km in this case. Without the addition of filters to Camera B, however, this would not provide data on the multispectral properties of the atmosphere above the limb.

Far-encounter multispectral imagery on the '69 Mariner could also provide an order of magnitude improvement in resolution for Mars color photography (compared to present earth-based telescopic results). A sequence of photos using different filters on Camera A at the time when the full disk fills the field of view (about 2 hours prior to periapsis) could provide the basis for a multispectral image of the Mars disk. At this distance (∿35,000 km) and approach velocity (∿6 km/sec), the limb of the planet would be moving across the field of view of the constant attitude camera at the rate of ∿3 scan lines/minute. There would be no apparent motion due to the approach velocity at the center of the visible disk. Maximum apparent motion due to the rotation of Mars would be at the rate of about 1 1/2 scan lines/minute at the center of the visible disk (at the Mars equator). So long as the pictures with alternate filter settings are taken over a period of time which is less than 1/3 minute, corresponding to a maximum displacement of one scan line, registration should be maintained between successive pictures.

IV. CONCLUSIONS

Two additional opportunities for data return from the 1969 Mariner flyby television experiment have been described. These are (a) the possible location of the moons of Mars in the far-encounter pictures, and (b) far-encounter photography using color filters to provide full disk multispectral imagery.

(a) Proper orientation of the rectangular field of view of the vidicon tube in the high resolution camera increases the probability that the moons of Mars will be detected in the planned far-encounter photogaphic sequence of '69 Mariner flyby mission. The probability of detecting Phobos ranges from 0 to about 15%, depending on the vidicon orientation, at the time when Mars fills the short dimension of the field of view. At this time the moons would appear as spots of light against the dark sky background, being only 1 scan line wide.

Obtaining full planet photographs of Mars showing both surface details and the moons would be a "first" and should have popular appeal. The scientific worth of photographing the moons at this resolution has not been analyzed. The photographs might improve the emphemeris data for the moons, especially if taken in conjunction with simultaneous earth-based photography. No improvement in the diameter estimates could be made from this distance unless the moons prove unexpectedly large.

The Mariner high resolution camera does have the capability to provide significant data on the size, shape, and general appearance of the moons of Mars at a closer range. At 20,000 km the high resolution camera would have about 18 scan lines across Diemos and 35 scan lines across Phobos. The Mariner spacecraft will probably get at least this close to the moons since the orbital radii are 9300 km for Phobos and 23,400 km for Diemos and the spacecraft will fly by about 6400 km from the center of Mars. It is also possible that such high resolution photography will detect new satellites of Mars which have not previously been observed from earth. Photographing the moons at close range during the encounter would require deviation from the planned encounter photographic mission.

(b) While the nominal plan for far-encounter photography includes only black and white imagery with the narrow angle camera, there appears to be considerable merit in augmenting the mission by taking a series of full planet pictures with the wide angle camera so that multispectral data can be obtained. Such pictures would represent an improvement in resolution over available earth-based telescopic data and would be generally useful in studying the global color properties of the surface and atmosphere of Mars. As the current camera system includes only an orange and green filter, consideration should be given to including a blue filter to better observe the properties of the so-called "blue haze."

In addition, it should be possible to improve the data on the Mars polar and equatorial diameters. This has been difficult to do photographically from earth. This data could be checked by the figures for planet radius derived from the occultation experiment results. The experiment is worth doing in multispectral imagery since astronomers have observed different radii throughout the visible spectrum. The variations are possibly due to atmospheric effects at Mars, but resolution has not been sufficient to demonstrate this conclusively.

Finally, two points are worth noting. One lesson learned from Mariner IV was that the interpretation of the near-encounter pictures would have been aided by far-encounter full planet photography, albeit at a lower resolution. Therefore, if it is expected that the Mariner '69 near-encounter pictures will contain multispectral information, it would seem logical to provide full planet multispectral pictures at the best possible resolution. This would entail modifying the nominal mission plan either to take pictures with the A camera (which has filters) about 2 hours before encounter, or take the planned far-encounter (about 20 hours before encounter) pictures with color filters added to the B camera.

Secondly, it is noted that full planet multispectral imagery of Mars cannot be taken from orbit during the proposed '71 mission, as the wide angle camera only subtends about half a planet diameter at apoapsis.* Therefore, unless photography is possible during the far-encounter portion of the approach trajectory on the '71 mission (at a time when preparations are being made for the orbit injection maneuver), the far-encounter phase of the '69 flyby could be the last opportunity for improved resolution full planet multispectral imagery of Mars for some time to come.

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Attachment
Figure 1

*Nominal apoapsis altitude is 17,000 km and the wide angle camera field of view is 11° and 14° (same camera system as Mariner '69).

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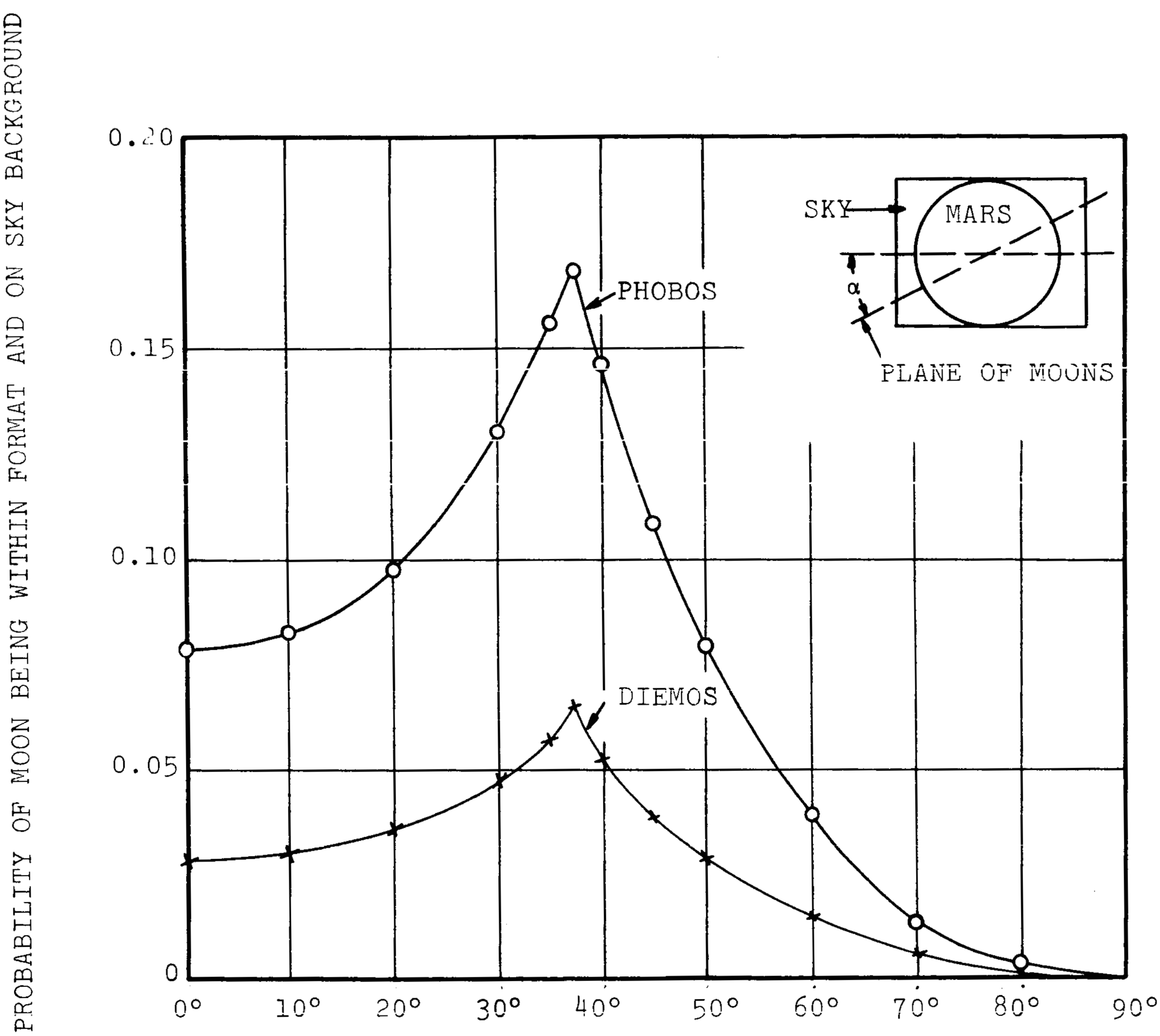

α - ANGLE BETWEEN LONG AXIS OF FORMAT AND THE ORBIT PLANE

FIGURE 1 - PROBABILITY OF INCLUDING PHOBOS AND DIEMOS IN FULL DISK MARS PHOTOGRAPH AS A FUNCTION OF FORMAT ORIENTATION

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